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Selected US specifications from IPC sub-class G01V

(54) Process for installing seismic sensors inside a petroleum production well equipped with a cemented casing

(57) It consists primarily of arranging seismic sensors (10) along the outer surface of the casing (2a, 2b) before being descended into a drilled well (1) and cementing the ring-shaped space so as to acoustically connect the sensors to the environmental formations. The sensors (10) and the transmission cables (11) which link them to the surface are secured to centering devices guiding the descent of the casing or to said casing's outer wall, possibly by means of a coating of damping material. Sensors may be inserted into sleeves secured outside the casing.

To be applied in seismic monitoring of a production well.

FIG. 1

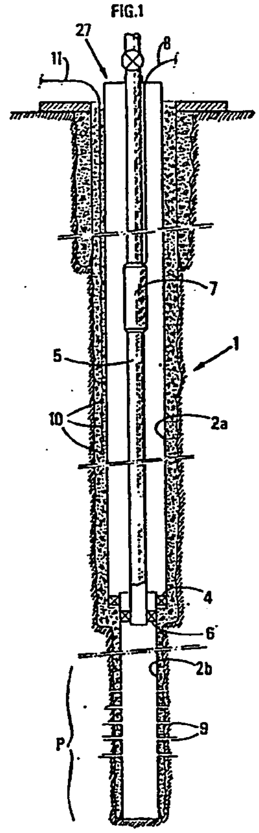

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FIG.1

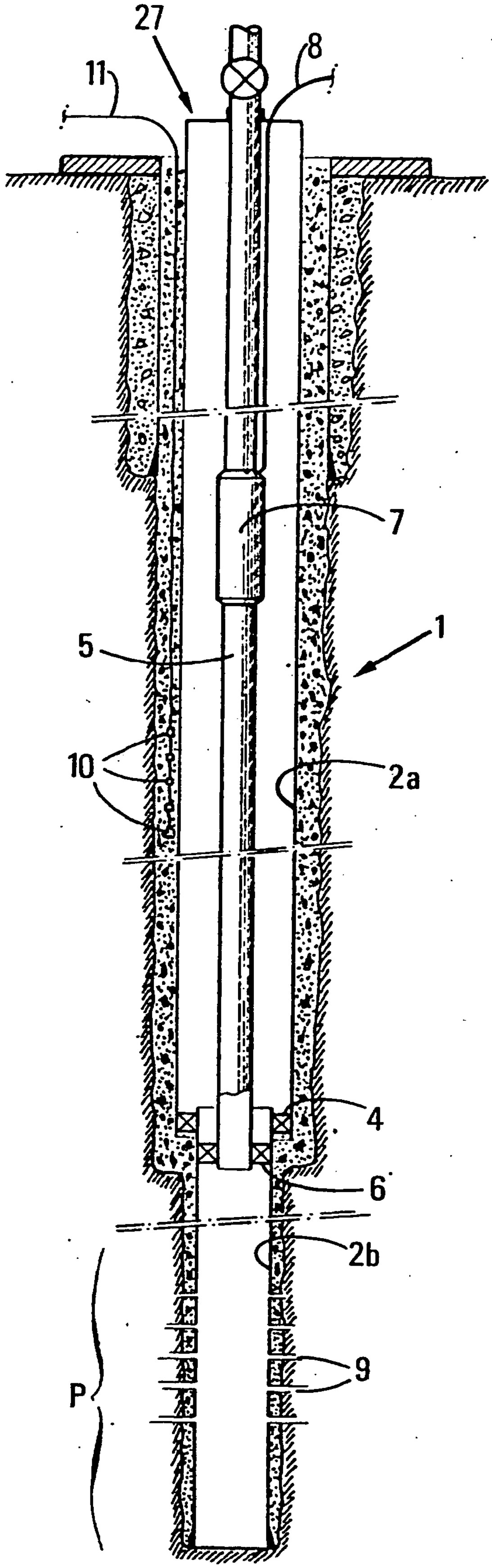

FIG.11

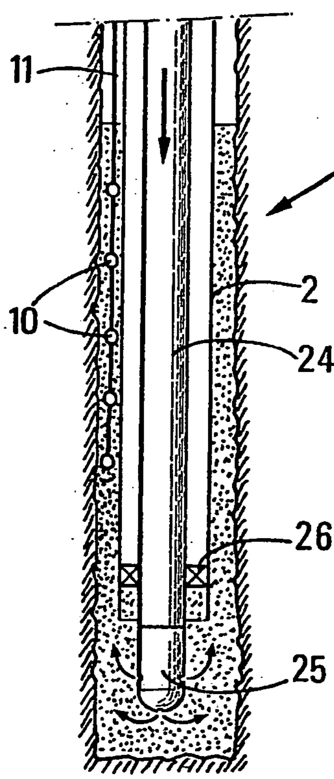

FIG.2

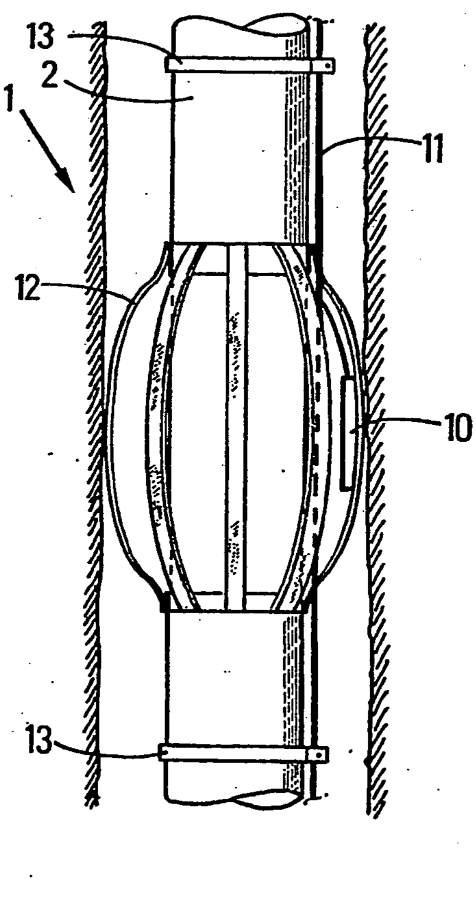

FIG.3

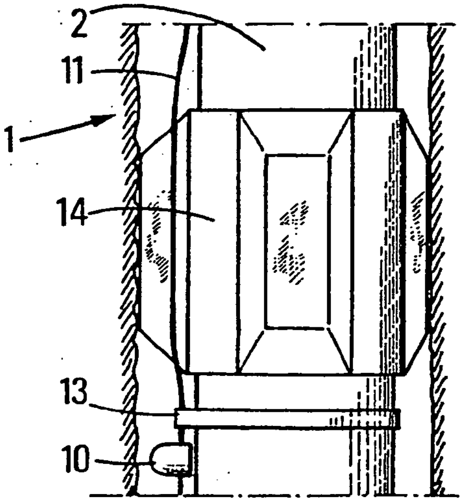

FIG.5

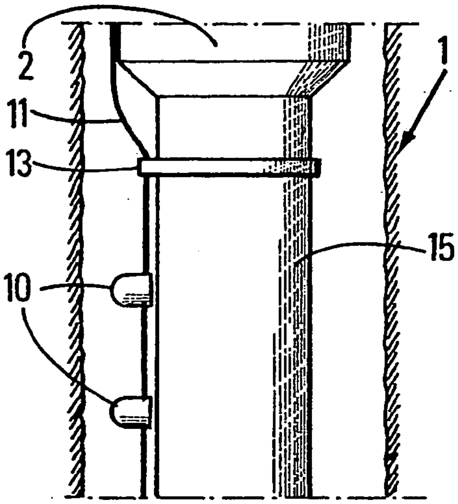

FIG.4

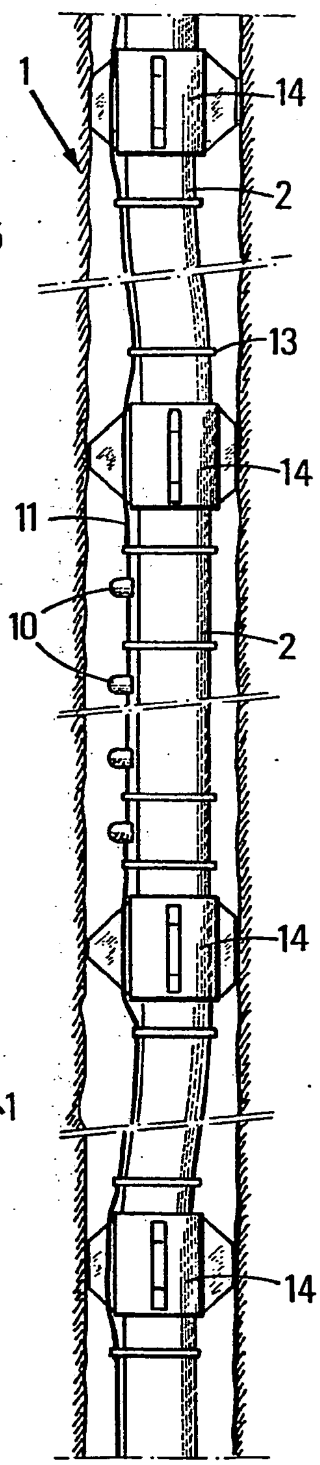

FIG.7

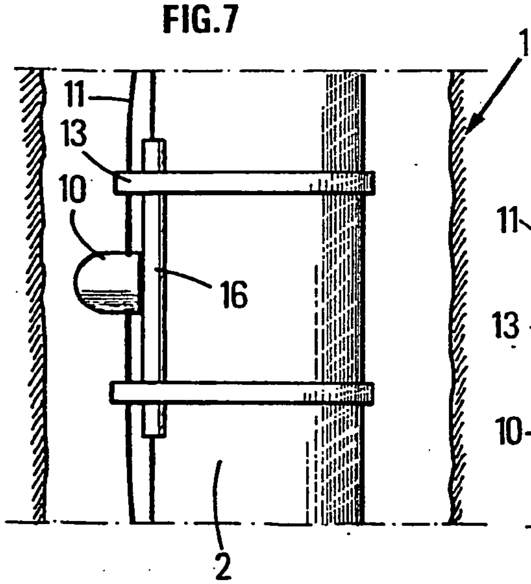

FIG.6

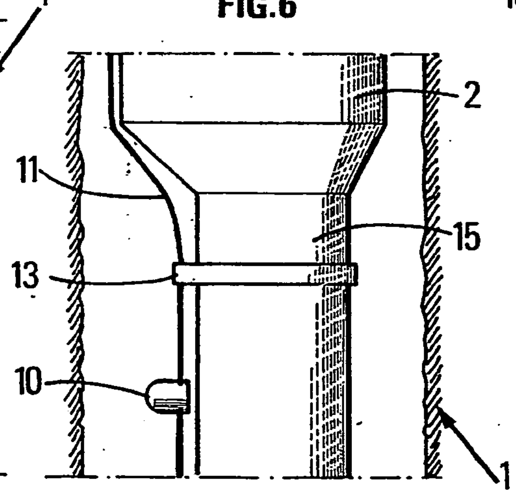

FIG.10

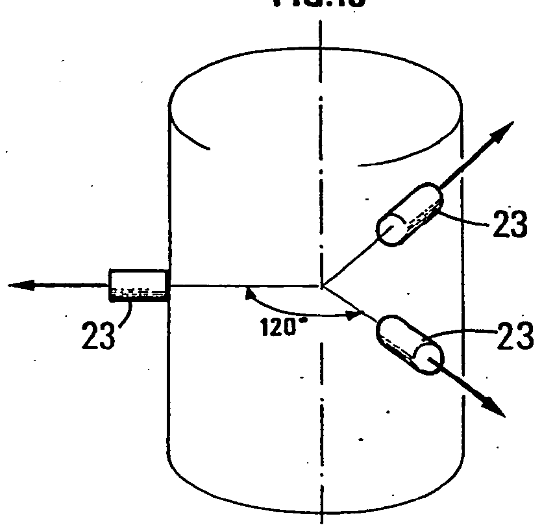

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FIG.8

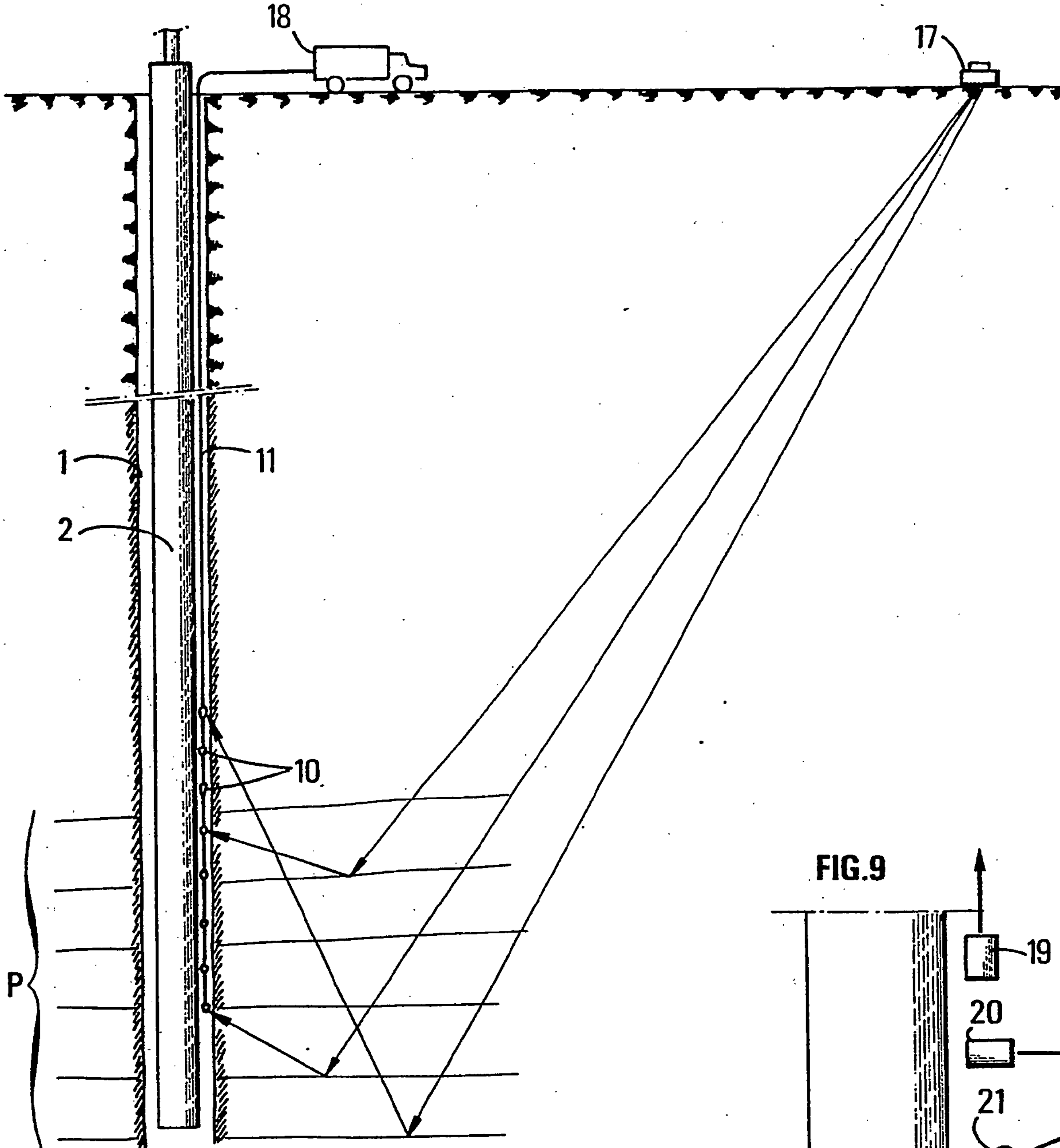


FIG.9

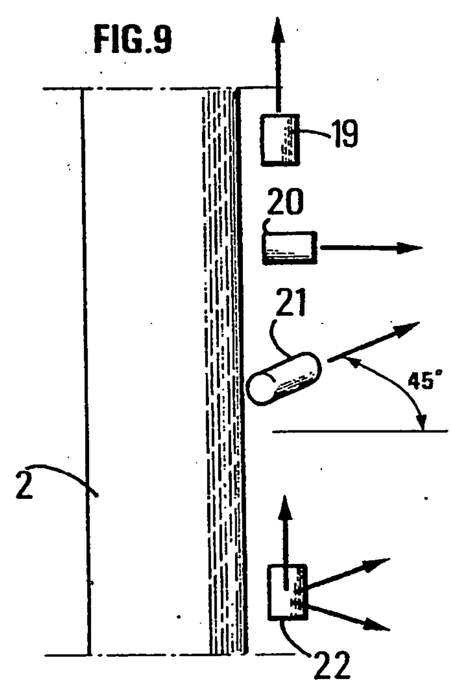


FIG.12

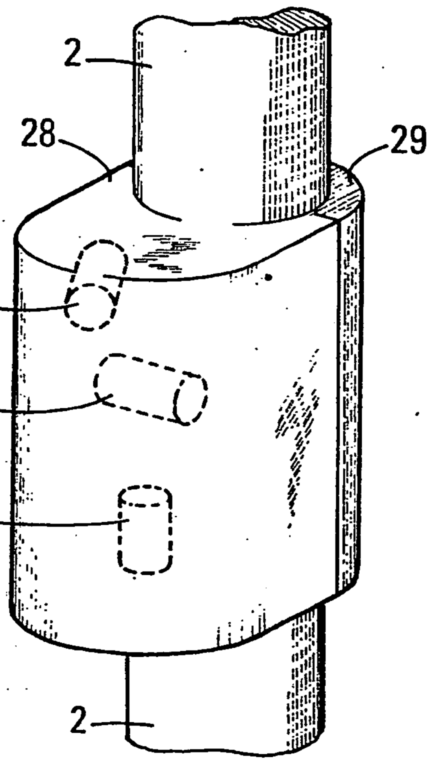
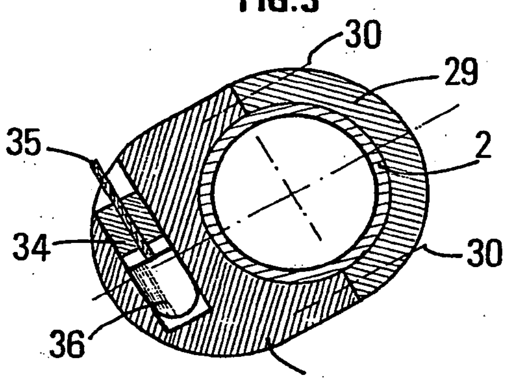


FIG.3



SPECIFICATION

Process and device for installing seismic sensors inside a petroleum production well

The invention concerns a process for installing seismic sensors inside a petroleum production well in order to carry out extremely diverse measurements concerning the state of the well, to monitor flow inside the well and also seismic readings enabling, in particular, evolution during time of the production zone to be determined.

Specialists are familiar with the uses of sensors inside wells equipped by production. For example, one of such uses consists of acoustically determining the quality of the borehole cementation coupling with the side wall, the outer pipe column or casing having been disposed therein. One conventional operation carried out in the completion phase of a drilled well consists of descending into it a casing and injecting cement into the ring-shaped space so as to prevent the fluids produced by the well from escaping or migrating through this channel. The quality of the cementation, upon which the imperviousness of the ring-shaped or annular space depends, is, for example, determined by bringing down into the tubed casing an elongated sensor containing acoustic receivers transmitters disposed at various depths. The transmitted acoustic waves are picked up by various receivers after propagation inside the ring-shaped zone and in particular inside the cement. A comparison of the signals received enables one to determine, for example, which distribution is thoroughly homogeneous.

Another familiar example of use consists of descending inside a tubed well a probe containing a large number of various sensors enabling various parameters to be measured, especially acoustic noise, natural radio-activity, temperature, pressure, etc.

Some known examples of the use of sensors inside tubed wells are described in the European patent applications n° 55634 or 98778 and the US patent n° 4.390.878.

The positioning of sensors inside a tubed shaft is suitable for carrying out localized measurements of a nearby ring-shaped zone or for monitoring fluid flows inside a tubing. But it is not suitable for, for example, determining using seismic methods the evolution of a reservoir in the course of operation. Seismic records are carried out, particularly by the method known as the vertical seismic profile method (VSP) which includes the reception of waves returned by various underground reflectors by means of a large number of geophones arranged at various depths inside a drilled well, these waves having been transmitted by a seismic generator disposed on the surface or possibly inside another well. The implementation of such a method using geophones descended into a fitted-out petroleum production well becomes much more difficult as the connection of the geophones with the environmental formations is made by means of a casing.

The process according to the invention allows for the installation of seismic sensors inside a drilled well equipped for producing petroleum fluids and comprising a cement-sealed casing inside the well. It is characterized in that the seismic sensors are disposed inside the casing and that they are imbedded inside the cement which ensures cementing of the casing.

The various seismic sensors are, for example, disposed at various depths outside the casing and are linked to the surface by electric conducting wires. At each level of depth, a sensor or set of sensors is disposed. When the casing is externally integral with guidance means, the sensors are, for example, secured to these guidance means, the conducting wires being maintained by rings against the outer wall of the casing. The guidance means may, for example, include flexible centering blocks. To facilitate the mounting of the sensors, it is preferable to use dissymmetrical guidance means which move the casing towards one side of the wellbore over one part of its length, the sensors being disposed on the side opposite the casing. It is also possible to use casings, whose transversal section is reduced at at least one part of their length, the sensors being disposed, in the reduced section of the casing, against the casing itself. For coupling of the sensors, a layer of damper material can be inserted between the sensors and the casing.

One advantage of the process of the invention is that the sensors are directly connected by the cement with the environmental geological formations. They can then be used to receive the seismic signals due to microseisms produced inside these formations during the well production period or those which are spread from a transmission point on the surface. This location or point may occur on the perpendicular line of the well or even over a direction determined in relation to the axis of the well or the well direction if the latter is contorted. A further possible application consists of receiving into a well the seismic signals emitted by a noise source disposed inside another well.

Sound connection between the sensors and the inside of the casing, obtained by the process according to the invention, also enables them to be used to detect the noises and vibrations resulting from flows circulating inside the well.

A further important advantage of the process lies in the fact that the installation of seismic sensors is very easily adapted to the equipment methods used in petroleum wells, the cementation also being used to couple the seismic sensors to the environmental formations.

Other characteristics and advantages offered by the process shall be revealed from a reading of a description of a number of embodiments given by way of example by no means restrictive and relating to the annexed drawings in which:

Figure 1 represents in a very simplified way a well equipped out for production where the outer casing is connected to a large number of seismic sensors imbedded inside the capping cement;

Figure 2 diagramatically represents a means for securing the seismic sensors outside the outer casing;

Figure 3 diagramatically represents a dissymetri-

cal centering member enabling the casing to be moved laterally over a certain length so as to enlarge the space where the sensors are disposed ;

Figure 4 diagramatically represents the layout of sensors inside the casing out-of-centre zone ;

Figure 5 diagramatically represents an embodiment where the sensors are disposed inside a ring-shaped space increased by a restriction of the casing ;

Figure 6 represents a variant of Figure 5 in which the casing restriction is dissymetrical ;

Figure 7 diagramatically represents another embodiment where a layer of damping material is inserted between each seismic sensor and the outer wall of the casing ;

Figure 8 is a sketch of a transmission/reception device enabling a seismic prospection of a well to be made inside a production zone ;

Figure 9 represents another embodiment in which directional sensors disposed at different depth levels can be used ;

Figure 10 shows an arrangement including three sensors disposed on the periphery of the casing and at 120° from each other ;

Figure 11 diagramatically represents a known device which is descended into a tubed well so as to inject the capped cement.

Figure 12 diagramatically represents a sleeve externally integral with the casing and provided with receptacles for the seismic sensors and

Figure 13 diagramatically represents the disposition of a seismic sensor inside its receptacle.

Figure 1 shows a well 1 which is drilled to a first diameter up to a certain depth and, especially through the production zone, to a second diameter less than the first one. The well is conventionally fitted out with a casing made up of two parts 2a and 2b with unequal sections adapted to the diameters of the drilling. The part with the smallest diameter 2b is fitted with a variable volume packer sealing device 4 which is expanded to wall-in the ring-shaped space between itself and the other section 2a having a larger diameter and close to one of their mutual extremities. Inside the casing and as far as its section 2b with the smaller diameter, a tubing 5 is disposed. Another packer sealing device 6 is disposed near to the inner extremity of the tubing 5 so as to wall-in, in an extended position, the ring-shaped space between it and the lower part 2b of the casing. A pumping unit 7 supplied by a feeding electric 8 is disposed on the tubing 5. The part of the casing 2b crossing the production zone P is provided with a number of orifices 9. A tubing head 27 fitted with valves closes the casing at its upper extremity.

The process according to the invention consists of disposing one or more seismic sensors inside the casing at its section having the largest diameter 2a (or its section having the most restricted diameter 2b if the volume of the outer ring-shaped space so allows) before it is descended into the wellbore. These seismic sensors are connected to the surface by one or more transmission cables 11. The next step is to cement the casing. To achieve this, as is already known, a tube 24 terminated by a special injection joining piece 25 and containing a reverse-lock valve is descended into the casing 2 as far as possible to its lower extremity. The tube 24 is immobilized by a packer sealing device 26 and cement is injected. The cement gradually fills up by ascending the ring-shaped space between the casing 2 and the hole 1. At the end of the cementing stage, all the seismic sensors 10 disposed inside the ring-shaped annular space are imbedded inside the cement.

Around the casing 2 and in order to facilitate its descent, centering elements 12 of a known type are fixed (Figure 2), these having flexible blades or radial blades, for example. According to another embodiment, the seismic sensors 10 are secured to centering elements 12. The connecting wire 11 (or wires if there are more than one) is kept against the outer wall of the casing 2 by the clamping collars 13.

When the volume of the boxes housing the used seismic sensors 10 becomes incompatible with the dimensions of the ring-shaped space between the drilling and casing 2, dissymetrical guidance elements 14 (Figure 3) can be used to bring the casing 2 out-of-centre along that part of its length along which are disposed the sensors (Figure 4). The seismic sensors can be secured to the guidance elements 14 or preferably, as shown by Figure 3, kept against the outer wall of the casing 2 by the fixing clamps 13 of the link cable 11, for example. It is also possible to use casings comprising (Figure 5 or 6) at least one section 15 whose diameter is restricted. The restricted part may be symetrical (Figure 5) or even dissymetrical (Figure 6) if all the sensors are disposed on the same side of the casing.

According to another embodiment, a layer of elastic material 16 is inserted between each seismic sensor 10 and the wall of the casing 2 (Figure 7) so as to acoustically uncouple the latter. The layer 16 may possibly be an outer coating of the casing.

All the seismic sensors 10 are disposed inside the ring-shaped space around the casing 2 so as to be used, as shown by Figure 8, to record seismic readings. A seismic source 17 (a vibrator or pulse source) generates on the surface of the ground seismic waves which spread out in depth. The waves sent back by the various underground reflectors, and in particular those of the production zone P, are received by the various sensors 10 and the seismic signals detected are transmitted by the transmission cables 11 to a recording laboratory 18.

The seismic sensors can also be used to perform seismic prospection operations from well to well or even to produce a non-functional monitoring of phenomena occurring inside a producing well (flow noises of fluids circulating inside the columns) or when production has stopped (detection of formation fracturings caused by the production or injection of fluids). The seismic sensors used are, for example, geophones or accelerometers. The number used and their disposition are selected according to the intended applications.

The sensors are disposed, for example, according to one and the same casing 1 generator, as shown by Figure 8. It is also possible to use directional sensors (Figure 9, 10) whose axes are tangentially directed towards the casing (sensor 19) or along radial directions (sensor 20) or even along intermediate dir-

ections (sensor 21). These intermediate directions can be contained inside the transversal plane, as shown by Figure 9, or even inclined towards the top or bottom in relation to such plane. At a given location, it is possible to dispose a box 22 containing 3 directional sensors orientated along three orthogonal directions.

It is also possible to dispose the sensors so as to determine the incoming direction of seismic signals. To this end, several directional sensors 23 are disposed on the periphery of the casing inside a given transversal plane at 120° from each other. According to the mode of embodiment of Figure 10, the axes of the sensors are disposed radially. But this is not restrictive. It is also possible to incline the axes of the sensors in relation to the transversal plane, either towards the top of the shaft or towards the bottom, the angle of slope being any size whatsoever.

In its most usual configuration, the set of seismic sensors may include several sets of sensors divided up along part of the casing, each of the sets comprising a number of sensors, possibly directional, and disposed on the periphery of the casing.

By way of example, one mode of embodiment allows several directional sensors to be connected to the casing and consists (Figure 12 and 13) of securing to the latter sleeves comprising one or more receptacles. Each sleeve has two female mouds 28, 29 enclosing the casing and joined together by bolts (whose axes are marked 30). The sleeve is dissymetrical. The thickest female mould (28) comprises three cylindrical receptacles 31, 32, 33 whose axes are oriented along three orthogonal directions, i.e. two inside a horizontal plane and the third being parallel to the axis of the casing 2. Each receptacle is closed by a sealed cover 34. A twin conducting wire 35 is connected to each geophone 36. Conventional means (not shown) are connected to the cover 34 so as to ensure imperviousness of the wire passage 35.

Each sleeve with three receptacles could be replaced by three sleeves having a shorter length, each comprising a receptacle, such as 31 or 32, whose axis is contained inside a transversal plane or a receptacle such as 33 whose axis is parallel to the casing 2. A change in orientation of a geophone inside a transversal plane is easily obtained by causing the sleeve 28 to turn in relation to the casing.

CLAIMS

1. Process for installing seismic sensors inside a drilled well (1) equipped for the production of petroleum fluids and comprising a casing (2) imbedded into the well by cementation, characterized in that the said seismic sensors (10) are disposed outside the casing and in that they are flooded into the cement which ensures bedding.

2. Process according to claim 1, characterized in that the various seismic sensors are disposed at various depths outside the casing and that they are linked to the surface by connecting wires (11).

3. Process according to claim 1, characterized in that at least one group of seismic sensors are disposed outside the casing approximately at a given depth, the sensors of each group being connected to the surface by connecting wires.

4. Process according to claim 3, characterized in that a large number of seismic sensor units are disposed a various depths.

5. Process according to claim 1 whereby the casing (2) is externally provided with guidance means (12, 14), characterized in that the seismic sensors are secured to the guidance means, the connected connecting wires being maintained by clamps against the outer wall of the casing.

6. Process according to claim 5, characterized in that the guidance means (14) are dissymetrical so that the casing (2) are removed towards one side of the well as regards at least one part of its length, the seismic sensors being disposed outside the casing on the opposite side.

7. Process according to claim 1, characterized in that transversal section of the casing is reduced on one restricted part (15) of its length, the sensors being disposed against the casing in said restricted part.

8. Process according to claim 1, characterized in that directional sensors (19, 20, 21) are used and that at least one directional sensor is disposed at each level of depth.

9. Process according to claim 8, characterized in that several sensors (22) are disposed at each level of depth so as to pick up polarized waves along several axes.

10. Process according to claim 3 or 4, characterized in that the directional sensors (23) are disposed on the periphery of the casing (2).

11. Process according to claim 1, characterized in that the sensors are geophones or accelerometers.

12. Process according to claim 1, characterized in that a layer of a damping material (16) is inserted between the sensors and the casing.

13. Device for installing seismic sensors inside a petroleum production well, characterized in that it includes at least one sleeve (28, 29) and means for securing the sleeve to the casing, the said sleeve including at least one receptacle for a seismic sensor (36).

14. Device according to claim 13, characterized in that the said sleeve comprises three cylindrical receptacles (31, 32, 33) whose axes are respectively orientated along three orthogonal directions.

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